INNOVATIVE TECHNOLOGY
Summary Report

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2-D Linear Motion System

Deactivation and Decommissioning Focus Area

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Summary Report

2-D Linear Motion System

OST Reference #1476

Deactivation and Decommissioning Focus Area

Demonstrated at
Hanford Site
Richland, Washington

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Summary Report

Purpose of this document

Innovative Technology Summary Reports are designed to provide potential users with the information they need to quickly determine if a technology would apply to a particular environmental management problem. They are also designed for readers who may recommend that a technology be considered by prospective users.

Each report describes a technology, system, or process that has been developed and tested with funding from DOE's Office of Science and Technology (OST). A report presents the full range of problems that a technology, system, or process will address and its advantages to the DOE cleanup in terms of system performance, cost, and cleanup effectiveness. Most reports include comparisons to baseline technologies as well as other competing technologies. Information about commercial availability and technology readiness for implementation is also included. Innovative Technology Summary Reports are intended to provide summary information. References for more detailed information are provided in an appendix.

Efforts have been made to provide key data describing the performance, cost, and regulatory acceptance of the technology. If this information was not available at the time of publication, the omission is noted.

All published Innovative Technology Summary Reports are available on the OST Web site at http://ost.em.doe.gov under "Publications."

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SECTION 1

The 2-D Linear Motion System (2-D LMS), also known as the Wall Walker™[1], is designed to remotely position tools and instruments on walls for use in such activities as radiation surveys, decontamination, and painting. Traditional (baseline) methods for operating equipment for these tasks require workers to perform duties on elevated platforms, sometimes several meters above the ground surface and near potential sources of contamination. The Wall Walker 2-D LMS significantly improves health and safety conditions by facilitating remote operation of equipment. The Wall Walker 2-D LMS performed well in a demonstration of its precision, accuracy, maneuverability, payload capacity, and ease of use. Thus, this innovative technology is demonstrated to be a viable alternative to standard methods of performing work on large, high walls, especially those that have potential contamination concerns. The Wall Walker was used to perform a final release radiological survey on over 167 m^2 of walls. In this application, surveying using a traditional (baseline) method that employs an aerial lift for manual access was 64% of the total cost of the improved technology. However, for areas over approximately 600 m^2, the Wall Walker would cost less than the baseline. Using the Wall Walker 2-D LMS, ALARA exposure and worker safety is improved, and there is potential for increased productivity. This innovative technology performed better than the baseline by providing real-time monitoring of the tool or instrument position. Also, the Wall Walker 2-D LMS can traverse any two-dimensional path at constant speeds of up to 18.3 linear meters per minute (60 linear feet per minute). The survey production rate for the innovative technology was about 0.6 m^2/min (6 ft^2/min); the baseline production rate was approximately 0.3 m^2/min (3 ft^2/min), using the same surveying instrument and maximum scanning rate.

■ Technology Summary

This section summarizes an improved technology that can be used to position tools and instruments remotely on high, vertical surfaces (building interior and exterior walls). The 2-D Linear Motion System (2-D LMS), also known as the Wall Walker™[1], is a semi-robotic remote operating system that consists of motorized pulleys with cables hooked to a shroud or holder for the tool. A programmable controller on the ground controls the precise location and speed of the tool used.

Problem Addressed

The U.S. Department of Energy's (DOE) nuclear facility decontamination and decommissioning (D&D) program requires buildings to be decontaminated, decommissioned, and surveyed for radiological contamination in an expeditious and cost-effective manner. Simultaneously, the health and safety of personnel involved in the D&D activities is of primary concern. D&D workers must perform duties high off the ground, requiring the use of manlifts or scaffolding, often, in radiologically or chemically contaminated areas or in areas with limited access. Survey and decontamination instruments that are used are sometimes heavy or awkward to use, particularly when the worker is operating from a manlift or scaffolding. Finding alternative methods of performing such work on manlifts or scaffolding is important.

[1] Wall Walker is a trademark of Pentek, Inc., Coraopolis, Pennsylvania.

The Wall Walker 2-D LMS allows D&D and survey instrumentation to be operated remotely from the ground, eliminating the need for work on manlifts or scaffolds, and minimizing work in proximity to contamination. In addition, the Wall Walker 2-D LMS provides a measure of precision and productivity that is not available with the baseline method, i.e., manned operation of D&D and survey tools. The model demonstrated is designed for remotely operating tools weighing up to 158 kg (350 lb) and models are available for up to 909 kg (2,000 lb).

Potential Markets / Applicability

The Pentek, Inc. Wall Walker 2-D LMS is useful at DOE or other federal or commercial sites where tools or instruments must be used on high, vertical, flat or slightly curved surfaces. Because it is remotely controlled, it is especially effective in areas that are contaminated or where personnel would otherwise be required to work from manlifts or scaffolding. Also, because the instruments can be interfaced with computer software applications, the Wall Walker 2-D LMS is useful for performing surveys in which an automatic mapping feature is desired.

Features and Components

- Two motorized pulleys temporarily mounted near top corners of the wall
- Two wire cables threaded through the pulleys to a tool holder/shroud
- Programmable controller at remote ground-level location controls motorized pulleys to provide desired position and speed of movement to the tool holder/shroud

Advantages of the Improved Technology

The following table compares the improved technology to the baseline in key areas:

Category	Comments
Cost	In this application, the baseline cost is 64% of Wall Walker; however, ALARA exposure and worker safety is improved.
Performance	Production rate is about 0.6 m^2/min (6 ft^2/min) for a release survey; baseline production is about 0.3 m^2/min (3 ft^2/min). Accuracy in positioning equipment was within 1% to 2%, speed control was within 7%, much better than baseline. Repeatability in relocating equipment to specific positions was within 2.54 cm (1 in.), which is comparable to baseline.
Implementation	No special site services are required for implementing this tool.
Secondary Waste Generation	Does not generate secondary waste.
ALARA/Safety	Use of this tool improves ALARA conditions and safety, significantly reducing exposure and risks of workers falling.
Ease of use	Easy to deploy and control, short learning curve. Requires minimal skills.

These comparisons and characteristics were determined from the demonstration:

- Production rate was twice as fast as the baseline when used with a survey probe scanning the walls at a rate of up to 10 linear cm/sec. The time savings occur because with the baseline, time is lost to reposition the aerial lift used to obtain access to all elevated areas of the walls.

- For a 167 m^2 survey, the cost was $3990, versus $2554 for a comparable survey using a baseline method. For surveying over approximately 600 m^2, costs would be less than the baseline. Items that significantly affect cost include production rate, setup time, purchase price, and wall area over which the system is deployed.

- Payload capacity was checked at 136 kg (300 lb) for the 158-kg model demonstrated, which is greater than the weight of most tools typically used for surveying or decontamination activities.

- Demonstrated maneuverability around/over wall protrusions so that scanning proceeded without interruptions. (The baseline technique is needed if characterization or decontamination is needed in the vicinity of protrusions.)

The cost estimate and computed breakeven point are based on using the Wall Walker for a free-release survey, as was done in the demonstration. For a different scenario with a wall in a contaminated area, the personnel at the wall would have to be in full personal protective equipment (PPE) if using the baseline technology for the entire wall area. With the improved technology, full PPE would apply only for the mounting pulleys, installing cable, and scanning missed areas at the top, side, and near protrusions. The baseline production rate would be even slower and baseline costs would be higher than for the scenario used in the cost analysis. This would be true with either a manlift or scaffold used for the baseline.

Operator Concerns

Cables must be properly rated for the loads being deployed. While there is no need for workers to be directly under the wall walker equipment could be damaged if cables failed or instruments were not properly secured. Normally, the system computer can be located in a relatively clean zone, away from the contaminated surface.

Skills/Training

Required instruction in the use of the system was minimal for D&D workers and radiological control technicians (RCTs) (approximately 1 hour of instruction).

■ Demonstration Summary

The system was demonstrated by the C Reactor Technology Demonstration Group and the vendor from September 22 to 26, 1997. The Wall Walker 2-D LMS was demonstrated on approximately 195 m^2 (2100 ft^2) of exterior walls of the Hanford Site's C Reactor front face work area, side by side with a traditional (baseline) method, use of an aerial lift for manual access, for free-release radiological surveys. The system's payload weight capacity was also assessed for potential deployment of decontamination tools.

Regulatory Issues

The Wall Walker 2-D LMS is used to deploy instruments and tools, and there are no special regulatory permits required for its use. This system can be used within the requirements of 10 *Code of Federal Regulations* (CFR), Parts 20 and 835, and proposed Part 834 for radiological protection of workers and the environment, and Occupational Safety and Health Administration (OSHA) guidelines (29 CFR).

Technology Availability

The Wall Walker 2-D LMS technology demonstrated at the C Reactor was the first such demonstration for characterization at a DOE site. The system is available from Pentek, Inc.

Technology Limits/Needs for Future Development

The Wall Walker model demonstrated was specified to reach wall dimensions of approximately 15 m (50 ft). Since the system would be useful for a variety of tools and Pentek, Inc. has designed only a few holders, additional holders would need to be developed to increase the utility of the system. This technology is not well suited to walls that have many protrusions; rather, it works better on flat or slightly curved surfaces.

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Other
All published Innovative Technology Summary Reports are available at http://em-50.em.doe.gov. The Technology Management System, also available through the EM50 web site, provides information about OST programs, technologies, and problems. The OST reference # for the 2-D Linear Motion System is 1476.

SECTION 2

TECHNOLOGY DESCRIPTION

■ Overall Process/Technology Definition

The Wall Walker 2-D LMS is a remote operating system that can precisely control and maneuver tools and instruments over large vertical surfaces. It consists of motorized pulleys with cables hooked to a holder for tools and instruments. The motor-driven pulleys can be attached to the wall temporarily with magnetic force on steel walls, or with anchors or vacuum force on concrete walls (see Figure 1). The system is controlled at a remote station (Figure 2) by a programmable controller. For locations with no ceiling obstruction, the pulleys can be attached to standoffs above the wall, thereby allowing the end effector to reach the full height of the wall. Otherwise, up to 1.8 vertical meters (6 vertical feet) at the top of the wall cannot be reached. Similarly, if there are no sidewall restrictions, the standoffs can be positioned to allow reaching the full wall width instead of missing 0.3 to 0.6 m (1 to 2 ft) at the sides. The pulley assemblies weigh 22 kg (50 lb).

Figure 1. Wall Walker demonstration.

Figure 2. Remote control station.

Features and Components

The Wall Walker 2-D LMS has the following features and components:

<u>Features</u>

- Provides accurate and consistent scanning conditions for surveys (i.e., instruments can be accurately positioned and the scanning speed can be easily controlled).
- Is easy to maneuver and easy to learn to use.
- Has sufficient payload capacity to remotely operate D&D and survey tools up to at least 136 kg (300 lb), as demonstrated.
- Its remote operation improves ALARA exposure conditions over baseline methods.
- Has the capacity to use a variety of software that can be adapted to provide survey data and/or automated mapping of measured radiation levels (such as the Laser-Assisted Ranging and Data

System [LARADS]).

- The holder can be retrofitted to operate a variety of survey or decontamination tools.

Components

- Two high-strength steel cables, managed by servo-motor-driven pulleys.
- A device suitable for holding the tool or instrument that is attached to each cable with a yoke and clevis.
- The holding device used for holding decontamination tools or scanning instruments is a shroud, fitted with casters for smooth traversing, that is held against the wall with either vacuum force or with out-rigged weights.
- A vacuum hose fitting in the shroud to accommodate vacuum force and/or high-efficiency particulate air (HEPA) filtration system.
- A programmable controller at ground level with touch-screen controls and appropriate software.

The programmable controller demonstrated was programmed by Pentek using Parasol II software on a desktop computer. The maximum distance between the remote control station and the wall was set by the cable length, which was 15.2 m (50 ft) for the demonstration. Presently, Pentek uses a personal computer (PC) in the field instead of a programmable controller. The new computer is Pentium based with Windows 95 operating system and a modem that allows placement of the control system at any desired distance from the wall via telephone wires.

The operator can command the system (see Figure 2) to traverse any two-dimensional path at constant speeds of up to 18 m/min (60 ft/min). Using the programmable controller, the operator can either pre-program the pathways or manually guide the traverses. The motions can readily be rehearsed prior to applying the tool. A device suitable for holding the tool or instrument and that is attached to each cable with a yoke and clevis must be obtained from the vendor or fabricated especially for the intended service. Pentek has standard tool holders with shrouds available for a variety of decontamination/characterization devices. The shroud is held against the wall with either vacuum force or with out-rigged weights and is fitted with casters for smooth traversing. For example, an aggressive concrete decontamination tool can be held in a shroud with a vacuum hose that is connected at ground level to a filtration unit. If the wall has protrusions (e.g., piping or conduit runs), a tether attached to the shroud can be manually manipulated at ground level to temporarily pull the end effector away from the wall. Present Pentek system designs can operate with shroud/tool combinations weighing up to 453 kg (1,000 lb). Potential applications of the system include radiation surveys, marking designated areas, decontamination, and painting.

Two high-strength steel cables are managed by servo-motor-driven pulleys that are attached or suspended to the upper left and right sides of the wall. Both cables are joined together near a single point where the end effector is attached. The length of each cable is precisely controlled by a computer that directs the pulley motors. With the software employed in the Pentek Wall Walker 2-D LMS, the lengths of each of the two cables are known from automatic monitoring of the cable lengths paid out or retrieved. The position of the tool holder is displayed as X-Y coordinates. The operator arbitrarily chooses the location of the X-Y origin -- typically the lower left corner of the surface. Software is used to correct for cable stretch in computing X-Y positions. The wall span and height that can be reached by the end effector is limited only by the length of cable furnished.

System Operation

Physical setup of the system was performed mainly by onsite personnel. The automatic positioning of the shroud holding the radiation detector was performed mainly by Pentek personnel; onsite personnel mounted pulleys and operated radiological survey instruments. The onsite personnel also received instruction from the Pentek personnel and practiced operating the linear motion system.

Setup Procedure

- Unpack equipment, set computer on a stand or table, and connect electric power.

- Set anchors in top corners of wall and bolt base plates and pulley motors.

- Thread cables through pulleys and connect to tool holder or shroud.

- Mount tool or instrument. If a vacuum filtration unit is to be used, connect vacuum hose to shroud. If surveying is to be done, set up detector communication system.

- Register zero-zero coordinates position, set corners coordinates of area on wall desired to be scanned,
pattern of movement and speed at computer.

Scanning

- Start and run until desired area has been completed.

- Set next corners coordinates and pattern of movement, and start again. When all the desired areas have been completed, disconnect and remove cables.

Demonstration Plan/Overview

Demonstration Site Description

At its former weapons production sites, the DOE is conducting an evaluation of innovative technologies that might prove valuable for facility D&D. As part of the Hanford Site Large-Scale Demonstration and Deployment Project (LSDDP) at the C Reactor Interim Safe Storage (ISS) Project, at least 20 technologies have been assessed against baseline technologies currently in use. DOE's Office of Science & Technology/Deactivation and Decommissioning Focus Area, in collaboration with the Environmental Restoration Program, is undertaking a major effort of demonstrating improved and innovative technologies at its sites nationwide. If successfully demonstrated at the Hanford Site, these innovative technologies could be implemented at other DOE sites and similar government or commercial facilities. The technology demonstration was conducted with Pentek personnel assisted by the DOE, Richland Operations Office (RL) Environmental Restoration Contractor (ERC), Bechtel Hanford, Inc. (BHI).

The demonstration was carried out September 22-26, 1997 at the C Reactor to conduct free-release surveys of large wall areas, and to assess the potential for the innovative technology to deploy decontamination tools. The primary objectives of the demonstration, key demonstration results, and a comparison of the innovative and baseline technologies are discussed in this section. The demonstration was carried out at the outer walls of the C Reactor front face work area. The walls involved were 14.3 m (47 ft) high by 4.3 to 18.3 m (14 to 60 ft) wide, and had previously been surveyed only near ground level up to 2.4 m (8 ft) high. The radiological detection system used was an Eberline 380 alpha and beta/gamma probe with an Eberline 600 meter. Readings of radiation levels were transmitted automatically by radio to a portable ground-based LARADS receiving station and computer that operated independently from the LMS.

Demonstration Objectives

Specific performance objectives included the following features:

- Ability to provide robotic positioning and travel on walls guided by both a programmable computer and a manually controlled work station (joy stick), at least 15.2 m (50 ft) distance from the wall, that remotely controls movement of survey (characterization, pre- and post-decon, etc.) instrumentation probes and decontamination tools.

- Ability to deploy one of the baseline decontamination tools and survey probe on at least two walls to evaluate operation and setup.

- Capable of lifting and moving probes and tools with their associated hoses and cables to a height of 12.2 m (40 ft), and coverage of a wall 15.2 m (50 ft) wide with one setup. The location precision shall be ± 2.5 cm (1 in.). Computer control shall be capable of positioning a working tool on a vertical surface with a repeatability within 0.16 cm (1/16 in.).

- Ability to lift and move working loads with maximum weight of 159 kg (350 lb).

- Easy to decontaminate with conventional equipment.

- Ability to operate in an ambient temperature environment from 3°C to 40°C.

Demonstration Chronology

The radiation detector and automatic mapping system used was the LARADS, which was also used for the demonstration of the baseline method. Although the Wall Walker 2-D LMS computer could be adapted to perform mapping, during the demonstration it was used only for automatically positioning the radiation detector and setting the scanning speed. For the baseline demonstration, exterior concrete walls of the same height at the same building complex were used. Required duration times for each task, such as setup, survey, and take down, were recorded. The demonstration was conducted as follows:

Improved Technology

- The equipment was unpacked and set up on September 22-23, 1997. Onsite personnel were instructed by a vendor technician for a portion of the work. An RTC and D&D workers quickly learned the mechanical assembly and computer touch-screen control techniques. (Instruction took less than 1 hour, and it is estimated that complete adeptness could be achieved with an additional 3 hours of practice.)

- The Wall Walker 2-D LMS motorized pulleys were mounted near upper wall corners as would be done for deployment on interior walls with ceiling and corner interferences. With this configuration, 1.8 m (6 ft) of wall at the top and up to 0.9 m (3 ft) of wall at each side were not accessed by the Wall Walker 2-D LMS. Such areas that were omitted and areas near protrusions can be surveyed using the baseline method. In this case, the aerial lift used to aid in mounting the pulleys would be the choice for accessing areas needing manual surveying. The pulley assemblies were mounted by bolting them to concrete anchors after a manual radiation survey was performed at each mounting area.

- The radiation detector was mounted in a custom-fabricated shroud that was counter-weighted to cause pressure against the wall. The shroud was also fitted with casters, which were set to provide 0.6-cm (0.25-in.) standoff from the wall. (The shroud also had a vacuum hose fitting in the event vacuum force and/or HEPA filtration were desired.) Cable length was furnished for this demonstration sufficient to access walls up to 12 m (40 ft) wide by 15 m (50 ft) high. The cables were threaded through the pulleys by accessing with the aerial lift, and attached to the shroud at ground level. A rope attached to the shroud was used to manually pull the assembly over and around protrusions.

- Wall surveys, accuracy checks, and speed checks were done on September 24-25, 1997.

- The payload determination and packing for return shipment to the vendor were conducted on September 26, 1997.

Baseline Technology

The same aerial lift used to mount pulleys was deployed at an adjacent wall with a D&D worker and an RCT several days after the demonstration of the improved technology.

■ Technology Demonstration Results

Successes

- Used for survey of 195 m^2 (2,100 ft^2) of wall area at a pre-set standoff distance from the wall.
- The system was simple to deploy and the end effector was readily maneuverable around the desired walls area and over protrusions.
- Positioning accuracy was within 1% to 2%.
- Repeatability was within 2.5 cm (1 in.).
- Speed accuracy was within approximately 7%.
- The cable and pulley system furnished was rated at 158 kg (350 lb) payload, and was successfully demonstrated with a 136 kg (300 lb) payload.

Shortfalls

- The Wall Walker 2-D LMS is not suitable for surfaces that have many obstructions such as piping or conduit, because the wall area adjacent to such protrusions is missed.
- Currently, only a few shrouds are available to hold tools, which limits the number and type of tools that could be employed with the system. However, the technology provider should be consulted as they may be able to adapt the shroud to meet a user's specific need. The holder deployed was somewhat awkward to use.

Meeting Performance Objectives

The Wall Walker met the objectives listed in the Demonstration Overview section with the following exceptions and qualifications.

- The model furnished used a programmable controller instead of a computer. The programming was accomplished at the vendor's headquarters with a desktop computer. This arrangement proved to be adequate.
- Joy stick control was not demonstrated. The programmable controller with touch-screen controls proved to be adequate as demonstrated.
- Decontamination (concrete surface removal) tools were not demonstrated.
- Using the Wall Walker on a 15.2-m-wide wall with one setup was not demonstrated, but the cable lengths provided were capable of doing this.
- Repeatability of positioning was accurate to within 2.5 cm (1 in.), not 0.16 cm (1/16 in.), and is considered adequate for most survey and decontamination tasks on large walls surfaces.

- The system was tested with 136 kg of weights, not 158 kg. The wall decontamination tools used at the site weighed less than 136 kg. The vendor can supply cables and pulley motors rated for 909 kg (2,000 lb).

Comparison of Improved Technology to Baseline

Surveying with the Wall Walker 2-D LMS

Approximately 195 m^2 (2,100 ft^2) of wall area was surveyed. An 18-m- (60-ft-) wide wall was surveyed in two sections, each approximately 9 m (30 ft) wide. An 8-m- (27.5-ft-) wide section of another wall was surveyed. A demonstration of payload capability was conducted at a third wall. The target scanning speed for the 15.2-cm- (6-in.-) high radiation detector employed was 10.2 cm/sec (4 in./sec), with a 5.1-cm (2-in.) overlap for each horizontal scan that was performed, with the horizontal scanning speed set at 10.2 cm/sec (4 in./sec). The maximum production rate with these conditions is 0.6 m^2/min (6.7 ft^2/min). The survey production rate averaged 0.6 m^2/min (6 ft^2/min). The theoretical maximum production rate of 0.6 m^2/min (6.7 ft^2/min) was not attained because the Wall Walker 2-D LMS pauses slightly prior to each vertical move. Based on the measured durations, the setup/takedown time plus survey time would equal the baseline survey duration with the Wall Walker 2-D LMS deployed over 24.4 m^2 (263 ft^2). Approximately 5% of the wall areas covered was not scanned because of interfering protrusions; baseline surveying techniques (with the same aerial lift used to install the Wall Walker 2-D LMS pulleys) could be used for these areas.

The demonstration also showed that the positioning accuracy was within 1% to 2%, repeatability was within 2.5 cm (1 in.), and speed accuracy was within approximately 7%. These features were assessed using the following methods:

- Positioning accuracy was determined by entering desired coordinates into the system computer, allowing the system to automatically move the shroud accordingly, and checking the location physically. This routine was done again for three additional locations.

- Repeatability was determined by entering desired coordinates into the system computer, allowing the system to automatically move the shroud accordingly, and checking the location physically. This routine was repeated three additional times.

- Speed accuracy was determined by entering a desired travel speed into the system computer, allowing the system to automatically move the shroud accordingly, and checking the distance traveled and time manually.

To assess the potential for the system to be used for decontaminating walls, the following approach was used. The cable and pulley system furnished was rated by Pentek at 158 kg (350 lb) payload. Typical tools used routinely for aggressive concrete surface decontamination, such as scrabblers and vacu-blasters, weigh less than 136 kg (300 lb). The system was successfully demonstrated with 136 kg (300 lb) payload. This was accomplished by removing the shroud used to house the radiation detector and adding six 22.7-kg (50-lb) weights in its place. The system was then directed from the computer to move the weights horizontally, vertically, and diagonally over distances of approximately 6 m (20 ft) in each direction.

Onsite personnel were instructed by a vendor technician for a portion of the work. An RCT and D&D workers quickly learned the mechanical assembly and computer touch-screen control techniques.

Baseline Technology

The baseline method is to place personnel in proximity to the wall using scaffolding, aerial lifts, or scissor lifts. Exterior concrete walls of the same height and at the same building complex as were used for the innovative technology were surveyed. An aerial lift was used to provide technician access to a 14-m- (47-ft-) high exterior concrete wall for a release survey. (The same access method is used routinely for high interior walls.) The same radiation detector and automatic mapping system (LARADS) were used in the baseline demonstration as were employed for the demonstration of the Wall Walker 2-D LMS. The area surveyed was 4 m (14 ft) wide by 8 m (27 ft) high, near the top of the wall. As with the improved technology demonstration, the target scanning speed for the 15.2-cm- (6-in.-) high radiation detector was 10.2 cm/sec (4 in./sec), with a 5-cm (2-in.) overlap for each horizontal scan that was performed. The maximum production rate with these conditions is 2 m/min (6.7 ft/min). The actual production rate was 0.95 m/min (3.1 ft/min), allowing for overlaps that exceeded 5 cm (2 in.) and time lost due to intermittent repositioning of the aerial lift and 10% break time to rest fatigued arms. Essentially all of the wall that was to be surveyed (115.3 m [378 ft]) was surveyed with this method, and no substantial setup time or takedown time was required.

Table 1 summarizes performance and operation of the innovative technology compared to the baseline technology.

Table 1. Comparison of improved and baseline technologies

Activity or Feature	Improved	Baseline
Setup and take down time[a] (min)	45	5
Scanning rate	0.56 m^2/min (6.0 ft^2/min)	0.30 m^2/min (3.1 ft^2/min)
Scanning accuracy	Very accurately set scanning speed and overlap	Speed and overlap depends on RCT's judgement
Flexibility	Note b	Note b
Safety and ALARA	Workers and RCTs can stay at the ground level and far from the proximity to potentially high radiation exposure or high radioactive contamination	Personnel must work at high elevations in proximity to potentially high radiation exposure or high radioactive contamination
Durability	Computer, cables, and pulleys are subject to failures	More durable than innovative technology, less components associated with it that are subject to failure (but manlift still subject to failure)
Ease of operation	Not difficult to operate. Shrouds and tool holders need careful design	Easy, but leads to worker fatigue
Waste generation	None	None
Utility requirements	120 VAC	None
Training	Minutes of instruction on coordinate system, threading cables through pulleys and attaching it to the shroud, touch-screen computer operation	Minimal, operation and fall protection

NOTES:

a. Average time

b. The improved technology is flexible in terms of utilization of wide variety of instruments and tools. However, the baseline technology virtually has no limitation in this regard and is more flexible where there are protrusions. When the weight of instruments and tools are beyond the two-man lifting limit as prescribed by OSHA regulations, the improved technology can handle more weight.

Because of its variety of functions and facilities, the DOE complex presents a wide range of D&D work conditions. The working conditions for an individual job directly affect the manner in which D&D work is performed for an individual job. The innovative and baseline technology evaluations presented in this report are based upon a specific set of conditions or work practices present at the

Hanford Site, and are listed in Table 2. This table is intended to help the technology user identify work item differences between improved and baseline technologies.

Table 2. Summary of variable conditions

Variable	Improved	Baseline
Scope of Work		
Quantity and Type	Characterization of wall area of 167.2 m^2 (1,800 ft^2)*	Characterization of 35.1 m^2 (378 ft^2) area actually performed, the cost analysis is based on an assumed 167.2 m^2 (1800 ft^2)
Location	West and south side outer walls of Front Face Work Area	North outer wall of Front Face Work Area
Nature of Work	Survey of elevated and difficult to reach areas (height ranges from 5.8 m to 14.3 m [19 ft to 47 ft] above ground level) and wall width exceeded Wall Walker 2-D LMS span limits (could not cover with a single setup)	Survey of elevated and difficult to reach areas (height ranges from 5.8 m to 14.3 m [19 ft to 47 ft] above ground level). All work areas accessed by manlift
Work Environment		
Worker Protection	Hard hat, safety glasses, boots, and coveralls (non-rad zone)	Same
Level of Contamination	Assumed to be a buffer zone	Same
Work Performance		
Acquisition Means	Site workers and equipment	Site workers and equipment
Production Rates	33.2 m^2/hr (358 ft^2/hr)	17.3 m^2/hr (186 ft^2/hr)
Equipment and Crew	Anchors installation - manlift, two D&D workers and RCT (during survey of the installation area only) Survey - Wall Walker, LARADS, RCT and one D&D worker (may include a manlift on standby)	Two RCTs, one D&D worker, manlift, and LARADS

Work Process Steps	• Transport manlift and Wall Walker 2-D LMS from storage area • Set up equipment (i.e., Wall Walker 2-D LMS PC and LARADS) • Install anchor bolts and pulleys • Connect cable and tool holder/shroud • Survey • Decontaminate and release • Transport equipment back to storage area	• Transport manlift from storage area • Set up equipment (i.e., LARADS) • Survey • Decontaminate and release • Transport equipment back to storage area

* Even though during this demonstration 195 m^2 (2,100 ft^2) was surveyed, only 167.2 m^2 (1,800 ft^2) of the area was used for detailed comparisons because only 167.2 m^2 (1,800 ft^2) of the survey area was timed precisely.

Skills/Training

Required instruction for D&D workers and RCTs in using the system was minimal (less than 1 hour of instruction plus 3 hours of practice would be needed if deployed). Workers and RCTs needed basic knowledge of simple coordinate systems and needed to learn how to thread cable through the pulleys and to use the system computer touch-screen controls.

Operational Concerns

The main mechanical/structural concerns involve ensuring proper rating of cables employed for the payload and ensuring secure mounting of pulleys and associated instruments and tools. In most applications, there is no need for workers to be under the instrument or tool being deployed, so they would not be injured if components fell. However, expensive equipment could be damaged if cables failed or instruments were not properly secured. Also, if this system is used in radiologically contaminated areas, proper radiological work practices and engineering controls should be taken to prevent personnel or any system components from becoming contaminated. Normally, the system computer can be located in a relatively clean zone, away from the contaminated surface.

SECTION 4

TECHNOLOGY APPLICABILITY AND ALTERNATIVE TECHNOLOGIES

■ Technology Applicability

- This technology can be used at DOE and other public and commercial sites where large vertical surfaces must be decontaminated, surveyed, washed, marked, or painted.
- This technology is effective at radiologically and non-radiologically contaminated sites especially where personnel are required to wear protective equipment and/or perform tasks in high areas, or in areas with difficult access that otherwise would require lifts or scaffolding.
- The Wall Walker 2-D LMS can be used both inside and outdoors.
- This technology is well suited for applications of on-line characterization or decontamination tools and equipment.

■ Competing Technologies

This technology competes with other simple 2-D linear motion systems (window washers, painting systems, etc.), scaffolding, and manlifts. The competing technologies do not provide computerized positioning of the instrumentation; rather visual line of site is used. Therefore, competing technologies are not as effective at providing information for proactive decision-making regarding characterization and decontamination management.

■ Patents/Commercialization/Sponsors

This technology is patented and commercially available through Pentek, Inc.

SECTION 5

COST

■ Introduction/Methodology

This cost analysis compares the Wall Walker 2-D LMS innovative technology to the baseline technology of conventional radiological surveying. The principal focus of this cost analysis is the comparison of the delivery system (remote-controlled robotic system versus manual), and the radiological survey components are one potential aspect of the various D&D work activities that might be served by this technology. The improved technology was demonstrated using the vendor's personnel; however, the estimate is based on using site personnel, and assumes Government-owned equipment (the estimate was not adjusted for worker learning curve). The baseline technology was performed and estimated using site labor and equipment. The production rates and durations from the demonstration were used to estimate the cost of performing the survey of the exterior reactor wall. Both technology demonstrations were performed using the LARADS, but any delays in productivity caused by breakdown of the LARADS were excluded from the cost analysis. The estimated cost for characterization by the conventional radiological survey method is approximately 64% of the estimated cost for performing the characterization using the Wall Walker 2-D LMS technology. Details of the cost comparison are presented in Appendix C of this report and summarized in Figure 3.

■ Cost Analysis

The innovative technology is available from the vendor by purchase or vendor-provided service at the rates indicated in Table 3:

Table 3. Improved technology acquisition costs

Acquisition Option	Item	Cost
Equipment Purchase	Equipment & Accessories	$120,000
Vendor-Provided Service	Crew & Equipment Daily Rate	$3,000/day

The rates and prices shown (provided by the test engineer) do not include shipping or mobilization costs. The prices will vary from those shown because of shipping/mobilization distance and circumstances of the individual job (such as period of work). Rental/Lease is also an acquisition option in which the vendor would provide instruction. The vendor will provide current prices upon request.

Observed production rates and unit costs and production rates for principal components (setup and survey) of the demonstrations for both the innovative and baseline technologies are presented in Table 4:

Table 4. Summary of production rates and unit costs

Improved Technology Wall Walker 2-D LMS			**Baseline Technology** Manual Radiological Surveys	
	Production Rate	Unit Cost	Production Rate	Unit Cost
Survey Anchor/Setup Take Down	33 m^2 / hour (360 ft^2/hour)	\$3.92/m^2 (\$0.36/ft^2) \$280/ each set \$40/ each set	17 m^2 / hour (185 ft^2/hour)	\$8.71/ m^2 (\$0.80/ft^2

The unit costs and production rates do not include mobilization, demobilization, daily meetings, and productivity loss. The unit cost for Wall Walker 2-D LMS does not include the cost for LARADS, which was used to record the survey data, but is an optional cost (work could have been performed without using LARADS with the Wall Walker 2-D LMS).

The demonstration occurred under specific conditions that directly control cost (detailed tables of costs for the individual technologies are shown in Appendix C for the reader to compute the costs for site-specific quantities). The most significant conditions affecting costs and production rates for this demonstration were as follows:

- Survey of elevated and difficult to reach areas (height ranges from 5.8 m to 14.3 m [19 ft to 47 ft] above ground level)
- Wall width exceeded limits of cable length used (could not cover with a single setup)
- Number of obstructions impacted number of setups required
- Type of tool being deployed.

For additional discussion of cost variable conditions that may occur when using the innovative technology and the potential effect these conditions may have on unit costs and production rates, refer to Section 3 of this report.

■ Cost Conclusions

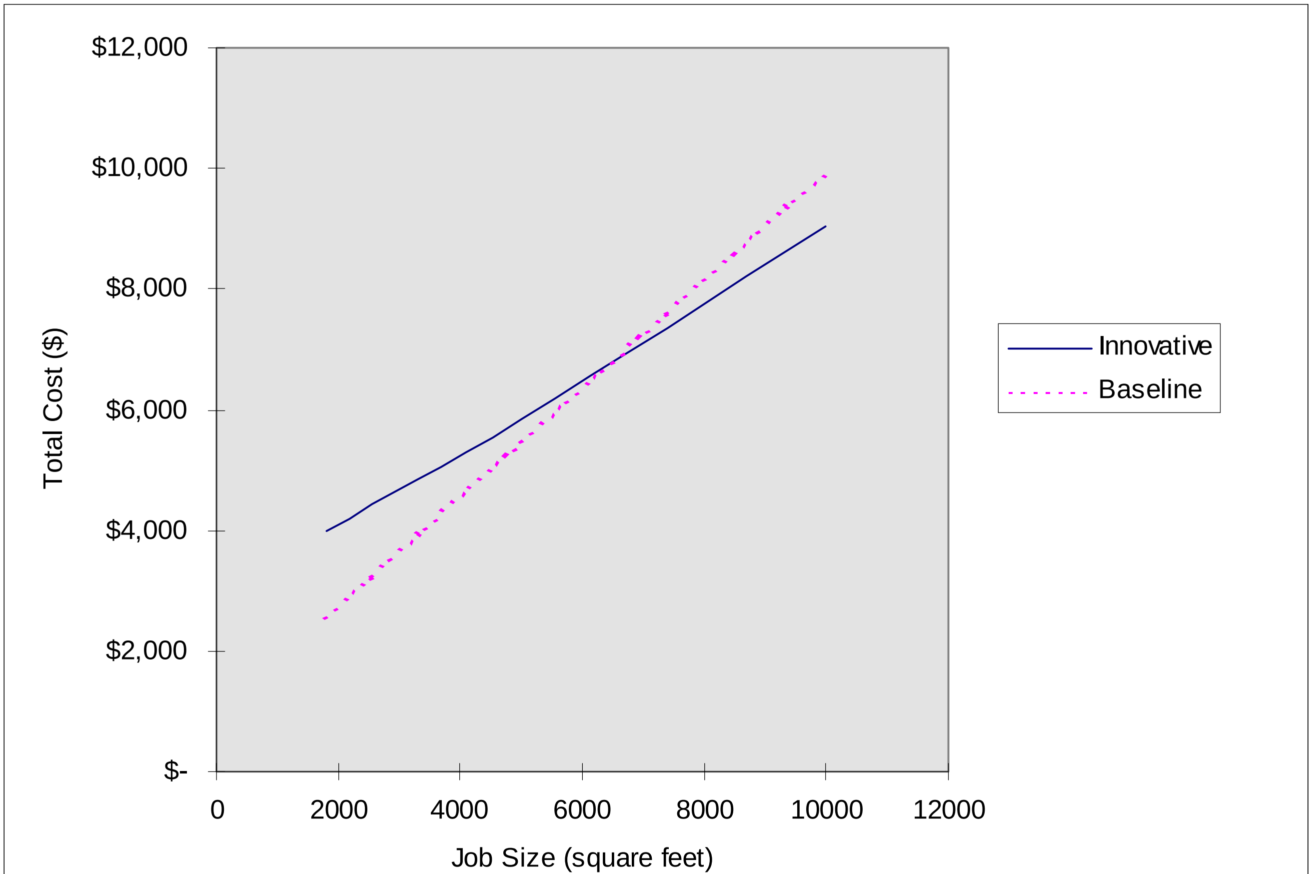
The durations and production rates observed from the demonstration were used along with the surface area quantity from an exterior reactor wall to estimate the cost of surveying the contaminated surfaces. Some of the demonstrated activities were not included in the cost estimate (such as training for site operators and preliminary surveys to locate the “hot spots”). The estimated costs for the innovative technology and the baseline technology are shown in Figure 3, which includes extrapolated values for walls areas up to 929 m^2 (10,000 ft^2). The costs are based on the following work activities:

- Transport from storage area
- Set up equipment
- Survey
- Decontaminate and release

- Transport back to storage area.

The costs shown in Figure 3 do not include overhead or General and Administrative markup costs.

Figure 3. Estimated costs for innovative and baseline technologies.



Note: Multiply square feet by 0.093 to obtain square meters.

The extrapolation to 930 m^2 (10,000 ft^2) assumes that there are six sets of anchor installations for the Wall Walker 2-D LMS and four repositions of the manlift for the baseline.

The estimate for this demonstration was based on three setups of the Wall Walker 2-D LMS because of the geometry of the areas being surveyed. The additional time required for installation of the anchors and attachment of the pulleys off-set the higher production rate and smaller crew size afforded by the Wall Walker 2-D LMS for the observed work (survey of 167.4 m^2 [1,800 ft^2]). The cost difference between Wall Walker 2-D LMS and the baseline would be greater than the amount shown in this estimate if the Wall Walker 2-D LMS costs were based on a vendor-provided service rather than on Government ownership. This is a significant factor considering the purchase price of $120,000.

During the demonstration, the Wall Walker 2-D LMS missed a maximum of 41% of the survey area because of obstructions. This estimate does not account for the areas that could not be reached (additional cost for survey by conventional methods).

The baseline used an aerial lift (manlift) to maneuver around the wall. The manual radiological survey missed less than 5% of the survey area because of obstructions. The costs for manual survey will vary depending on each individual D&D project. For example, it is possible that scaffolding would be required if other sites have areas not accessible by the aerial lift. Two carpenters at $45.85/hr would take approximately 3 hours to erect 8.2 m (27 ft) of scaffolding. As a result, the cost of manual radiological surveying would be significantly increased due to a scaffolding erection costs and due to a decrease in productivity associated with working from scaffolds.

The costs for both the Wall Walker 2-D LMS and the baseline technology are significantly affected by the geometry of the wall being surveyed. The geometry will determine the number of anchor installations and setups required for the Wall Walker 2-D LMS. For the baseline, the geometry of the wall will determine the number of times the manlift is repositioned or if scaffolding is required.

The Wall Walker 2-D LMS is capable of being equipped with a variety of attachments, including high-pressure blasting nozzles, concrete scabblers, paint heads, inspection cameras, radiation survey devices, and robotic grip actuators. In addition, the remote control and robotic capabilities eliminate some of the safety concerns involved with D&D work. Despite the determination that the Wall Walker 2-D LMS does not provide savings for the quantity of work in this demonstration, other types of work could result in cost savings. Specifically, those walls with geometry that make manual work difficult or pose a safety issue for the manlift could be cost-effective candidates if the number of Wall Walker 2-D LMS anchor installations can be minimized.

SECTION 6

REGULATORY AND POLICY ISSUES

■ Regulatory Considerations

- The linear motion system is used for remotely controlling instruments and tools. There are no special regulatory permits required for its operation.
- This system can be used in daily operations within the requirements of 10 CFR, Parts 20 and 835, and proposed Part 834 for radiological protection of workers and the environment, and OSHA guidelines (29 CFR).
- Although the demonstration took place at a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) site, no CERCLA requirements apply to the technology demonstrated.

■ Safety, Risk, Benefits, and Community Reaction

Worker Safety

- Precautions are needed to ensure that pulleys are mounted securely, that cables are rated appropriately and inspected/replaced as needed, and that personnel are not working beneath the system, thereby avoiding being hit by equipment if it falls.
- Normal radiation protection worker safety instructions used at the facility would apply when used in radiologically controlled areas.
- Technology users should implement contamination control practices when used in contaminated or potentially contaminated areas.
- Normal electrical safety and grounding requirements should be met.
- Normal worker safety precautions and practices prescribed by OSHA for operation of equipment should be followed.

Community Safety

- Implementation of the Wall Walker 2-D LMS is not anticipated to present any adverse impacts to community safety.

■ Environmental Impact

- No adverse impact on the environment would be expected to occur with implementation of the Wall Walker 2-D LMS.

Socioeconomic Impacts and Community Perception

- No socioeconomic impacts are anticipated due to implementation of the Wall Walker 2-D LMS. The community should favorably accept the use of such a system, as it increases worker safety and improves ALARA practice.

SECTION 7

LESSONS LEARNED

■ Implementation Considerations

- The technology can be used for interior and exterior areas. However, for outdoor applications, the computer screen should be shaded.
- The technology can be used in contaminated areas, usually with the computer workstation removed from the most contaminated surfaces. Otherwise, the workstation should be specially protected from contamination.
- The instrument shroud used for the demonstration was designed for temporary use and was awkward to employ. Holders or shrouds for instruments and tools need careful design and debugging.

■ Technology Limitations/Needs for Future Development

- A variety of tool holders need to be developed. Pentek has a few designs completed.
- The technology is not well suited to walls that have many protrusions.
- Pentek now can apply the technology to floors and ceilings.

■ Technology Selection Considerations

- The technology is suitable for DOE nuclear facility D&D sites or any other sites involving D&D or remediation activities in contaminated areas.
- The technology is suitable for washing, marking, or painting any large, flat, or slightly curved vertical surfaces.
- The technology inherently reduces the potential for personnel falling from lifts and scaffolds and for exposure to radioactive or chemical contamination.

APPENDIX A

REFERENCES

AIF, 1986 *Guidelines for Producing Commercial Nuclear Power Plant Decommissioning Cost Estimates*, May 1986, National Environmental Studies Project of the Atomic Industrial Forum, Inc., Bethesda, Maryland.

USACE, 1996, *Hazardous, Toxic, Radioactive Waste Remedial Action Work Breakdown Structure and Data Dictionary*, United States Army Corps of Engineers, Washington, D.C.

10 CFR 20, "Standards for Protection Against Radiation," *Code of Federal Regulations*, as amended.

10 CFR 835, "Occupational Radiation Protection," *Code of Federal Regulations*, as amended.

10 CFR 834, "Environmental Radiation Protection," *Code of Federal Regulations*, as proposed.

29 CFR 1910, "General Industry Occupational Safety and Health Standards," *Code of Federal Regulations*, as amended.

29 CFR 1926, "Construction Occupational Safety and Health Standards," *Code of Federal Regulations*, as amended.

APPENDIX B

ACRONYMS AND ABBREVIATIONS

Acronym/ Abbreviation	Description
2-D LMS	2-Dimensional Linear Motion System
ALARA	as low as reasonably achievable
BHI	Bechtel Hanford, Inc.
CFR	*Code of Federal Regulations*
D&D	decontamination and decommissioning
DOE	U.S. Department of Energy
ERC	Environmental Restoration Contractor
FETC	Federal Energy Technology Center
ft^2	square feet
G&A	General and Administrative
HEPA	high efficiency particulate air
HTRW	hazardous
ISS	interim safe storage
LARADS	Laser-Assisted Ranging and Data System
LMS	linear motion system
LSTD	Large-Scale Technology Demonstration
MCACES	Microcomputer-Aided Cost Engineering System
OSHA	Occupational Safety and Health Administration
PC	personal computer
PLF	productivity loss factor
RCT	radiological control technician
RL	U.S. Department of Energy, Richland Operations Office
USACE	U.S. Army Corps of Engineers
WBS	work breakdown structure

TECHNOLOGY COST COMPARISON

Technology Cost Comparison

This appendix contains definitions of cost elements, descriptions of assumptions, and computations of unit costs that are used in the cost analysis.

The selected basic activities being analyzed come from the *Hazardous, Toxic, Radioactive Waste Remedial Action Work Breakdown Structure and Data Dictionary* (HTRW RA WBS), USACE, 1996. The HTRW RA WBS, developed by an interagency group, was used in this analysis to provide consistency with the established national standards.

Innovative Technology - Wall Walker 2-D LMS

Costs for demonstration of the Wall Walker 2-D LMS innovative technology are based on performing a survey of 167.4 m^2 (1,800 ft^2) of exterior reactor wall. This scenario is intended to represent the cost for normal D&D work using the Wall Walker 2-D LMS (normal being defined by the vendor experience and judgment of the test engineer) and does not follow the sequence of events of the demonstration. The demonstration included scans of the west- and south-facing of a exterior reactor wall for contamination.

Adjustments of the observed data from the demonstration are shown below:

- Work will be performed assuming the equipment is purchased and operated by site workers (rather than lease of equipment or vendor-provided service) because of the many number of opportunities to use the equipment, cost for mobilizing vendor personnel, and the relative ease of learning to operate the equipment. The purchase price and shipping cost for the equipment was amortized using a discount rate of 5.8% as described in Office of Management and Budget Circular Number A-94.

- Wall Walker 2-D LMS equipment hourly rates were based on purchase price quotes provided by the vendor that were amortized.

- Rates for the manlift, LARADS, and other miscellaneous equipment (e.g., the truck and crane used in transport) are based on standard hourly rates used at the Hanford Site.

- Delays caused by breakdowns of the LARADS are not included in the productivity rates of the cost analysis, since the main focus was on Wall Walker 2-D LMS rather than on the LARADS (other tools could have been deployed rather than a radiological survey tool).

- The worker clothing consisted of a hard hat, coveralls, and boots. Since the protective clothing for this demonstration is not a significant cost item, PPE costs are not considered.

- The vendor personnel, as well as the RCT and D&D personnel, were present throughout the demonstration, which is assumed not to represent normal work.

The activities, production rates, and unit costs observed during the demonstration are shown in Table C-1, Innovative Technology Cost Summary Table, for use in developing a site-specific cost estimate.

The LARADS costs are shown as a distinct line item, and can be separated from Tables C-1 and C-2 in order to distinguish 2-D LMS costs from costs associated with the use of a particular tool.

Table C-1. Innovative technology - Wall Walker 2-D LMS

Work Breakdown Structure (WBS)	Unit Cost (UC) Labor Hours	Labor Rate	Equipment Hours	Equipment Rate	Other	Total UC	Total Quantity (TQ)	Unit of Measure	Total Cost (TC) note	Comments
Mobilization (WBS 331.01)								**Subtotal**	**$ 636**	
Load Equipment	1.00	$ 79.92	1.00	$ 86.58		$ 166.50	1	Each	$ 167	Teamster @$36.35/hr and truck @ $9.52/hr, crane @ $28.46/hr and operator @ $43.57/hr. Includes standby for Wall Walker @ $37.03/hr, survey probe @ $0.94/hr, and manlift @ 10.63/hr
Transport	1.00	$ 36.35	1.00	$ 58.12		$ 94.47	1	Each	$ 94	Teamster and truck to transport from storage area to C-Reactor. Includes standby for Wall Walker, probe, and manlift
Unload Equipment	1.00	$ 79.92	1.00	$ 86.58		$ 166.50	1	Each	$ 167	Same as load equipment
Unpack & Preassemble	0.75	$ 63.94	0.75	$ 48.60		$ 84.41	1	Each	$ 84	Two D&D workers @ $31.97/hr and equipment standby
Setup LARADS	0.73	$ 162.84	0.73	$ 7.50		$ 124.35	1	Each	$ 124	Includes setup and source check, etc, two D&D workers, two RCT's @ $49.45/hr each and includes LARADS standby @ $7.50/hr
Decontamination & Decommissioning (WBS 331.17)								**Subtotal**	**$ 2,406**	
Equipment Check & Preparation	0.67	$ 113.39	0.67	$ 48.60		$ 108.00	3	Survey Areas	$ 324	One RCT, two D&D workers, Wall Walker, and manlift
Install Anchors and Pulleys	2.52	$ 63.94	2.52	$ 48.60		$ 283.24	3	Survey Areas	$ 850	Two D&D workers, Wall Walker, and manlift
Radiological Survey of Anchor Area	0.27	$ 49.45				$ 13.19	3	Survey Areas	$ 40	
Wall Survey										
Wall Walker	0.0028	$ 81.42	0.0028	$ 37.03		$ 0.33	1,800	Square Feet	$ 596	One RCT, one D&D worker, Wall Walker, and manlift
Manlift	0.0028		0.0028	$ 10.63		$ 0.03	1,800	Square Feet	$ 54	
Take Down	0.34	$ 63.94	0.34	$ 48.60		$ 38.75	3	Survey Areas	$ 116	Two D&D workers, standby for Wall Walker and manlift
LARADS			15.62	$ 7.50		$ 117.12	1	Each	$ 117	Includes standby during non survey activities (RCT operation of LARADS covered under survey wall)
LARADS Data File Registration	0.15	$ 81.42	0.15	$ 48.60		$ 19.50	1	Each	$ 20	Crew and equipment on standby
Pre-Job/Safety Meeting	0.50	$ 81.42	0.50	$ 56.10		$ 68.76	1	Each	$ 69	Crew containing one D&D workers and one RCT
Productivity Loss Factor	1.61	$ 81.42	1.61	$ 56.10		$ 221.64	1	Each	$ 222	Productivity Loss Factor of 1.10 (adjusts for breaks extending the work duration by 10%)
Demobilization (WBS 331.21)								**Subtotal**	**$ 948**	
Decon and Survey Out	4.00	$ 81.42	4.00	$ 48.60		$ 520.09	1	Each	$ 520	Survey equipment for free release. Crew of one D&D worker and one RCT, plus standby for Wall Walker, probe, and manlift
Load Equipment	1.00	$ 79.92	1.00	$ 86.58		$ 166.50	1	Each	$ 167	Same as Mobilization Item
Transport Equipment	1.00	$ 36.35	1.00	$ 58.12		$ 94.47	1	Each	$ 94	Same as Mobilization Item
Unload Equipment	1.00	$ 79.92	1.00	$ 86.58		$ 166.50	1	Each	$ 167	Same as Mobilization Item
Note: TC = Total UC x TQ								**TOTAL:**	**$ 3,990**	